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ABSTRACT

Presented is an operational definition of science literacy including knowledge of science, the processes of science, the nature of science and the social implications of science. Future-oriented supplemental teaching materials are proposed as the most viable alternative available for achieving literacy in science within the present school curriculum, with a minimum of investment and with little or no retraining of present personnel. The proposal to use the future as an organizing principle is based on the recognition that future-oriented rules and procedures are an indigenous part of science, and that future projections and plans are a crucial part of our current social structure. Reference to the educational utility of future-oriented learning exercises is also made. Selected samples of future-oriented, teacher-based materials are included, along with several samples of student-run projects, also future-oriented. The benefits and costs are described in terms of social utility, added benefit to the scientific community, and fundamental benefits to students. Finally, research questions are posed which focus on the assessment of science literacy, as defined, along with additional basic questions about students' ability to deal with future-oriented topics as a function of cognitive age, sex differences and cultural differences. (Author/BR)

SCIENCE LITERACY AND ALTERNATIVE FUTURES

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SCIENCE LITERACY AND ALTERNATIVE FUTURES

INTRODUCTION

Science literacy has been defined by numerous observers of the educational establishment (1, 2) as including reference to science for citizenship and concern for the knowledge of science with some attention to the processes of science. Other observers (3) have evolved a more detailed structure of science literacy as including reference to science and society, ethics of science, nature of science, conceptual knowledge, science and technology and science and humanities. This, in turn, has led to a four-part operational definition of science literacy (4) which can be summarized as follows:

1. Basic scientific knowledge
2. Nature of science
3. The processes of science
4. Social and cultural implications of science

Given this operational definition, it is possible to examine the existing school science curricula to ascertain the extent to which each of the four areas of science literacy is developed. Non-rigorous examination shows most texts are deficient in social and cultural implications with varying degrees of coverage of the processes of science and the nature of science. It is clear that in some courses, reference to technological applications and social implications, and applications of scientific knowledge have been systematically avoided or reduced. There is evidence that much work needs to be done if high school graduates are to be literate in science.

- - THE NEED FOR SCIENCE LITERACY

The need for increased literacy in the sciences has been expressed by many science educators and, more recently, expressed in pronouncements from

the National Science Foundation. In a current publication (5), the Foundation lists as a major program objective:

> To improve science education to meet the needs of a broader range of students, and to increase substantially the number of persons who make effective use of the processes and results of science in their work and personal lives, whether or not they are engaged in scientific or technical occupations; and understand public issues involving science and technology.

In other words, the National Science Foundation has declared as a major program category, the "development of science literacy." The need for this effort is explained as follows: "As our society becomes more and more technologically based, more and more people are becoming engaged in activities or in making decisions that require a scientific or technical background, and there is an increasingly wide range of jobs at all levels for which science training is highly useful, if not essential." The Foundation is suggesting the development and implementation of materials which "offer a meaningful introduction to the fields concerned; are based on topics of inherent interest to children or teen-agers; require a 'hands-on' learning approach; serve as a sound foundation for later educational experiences; offer superior educational returns for little or no increase in investment; and can be used without long-term reorientation of school personnel." N.S.F. has opened the door for these developments, but lacks a defined program. It is up to the science education community to respond with proposals to improve the publics' image of and literacy in science.

Literacy in science implies not only an ability to read and communicate about science, but a willingness and, perhaps, even an eagerness to do so. At present, there is some evidence of a trend in the opposite direction within our society. There appears to be a prevailingly negative view of science, a sort of "disenchantment or uneasiness" about science as represented in some technological developments, particularly those that upset the human condition or environmental

factors. Roszak (6) has argued in several works that science and technology are dehumanizing, crushing the spirit of man. Many observers believe that science is not neutral and certainly not amoral, but is directly related to worsening human and world problems. It is up to us to develop a program which can intelligently and honestly examine both the constructive uses and the misuses of science.

The current call for increased science literacy is also related to evidence of decreasing enrollment in high school science, particularly in chemistry and physics, but also observed more recently in biology. Neither the causes nor the true extent of these purported declines have been adequately researched, but the consequences are enormous for us, our students and society in general. A few moments' reflection can convince most science educators that this is no time to be complacent about declining enrollments in our science courses. Perhaps the trend could be reversed if more students in physics considered applications and implications of science such as alternative energy sources and the limitations of these sources; or if students in chemistry explored future dependence of our society on petroleum for plastic products or for fertilizer production, and how these products are affected by the availability of energy and the costs; or if students in biology considered that in 1900, each calorie of food harvested required less than one calorie of agricultural effort, while today one calorie of food production requires an agricultural investment of over ten calories (7). These forces of science will continue to reshape our society, and, sooner or later, they will reshape the science curriculum too.

It is probable that the declining enrollment in science is in part related to a significant reduction in high school graduation requirements in the sciences. In many high schools, graduation now requires only one unit of

science which can be met with any science course, a home economics course or an agriculture course. This is, itself, a statement of the perceived need for science.

Changes in college entrance requirements represent another significant alteration in the regulatory structure which affects high school science enrollment. These requirements have been greatly eased in recent years. Even those colleges which have retained "rigid standards" have relaxed specific science requirements. Other campuses have gone to totally open enrollment policies. What prompted these changes? Is science seen as irrelevant? Was the change necessary to preserve the market? Or was no one there to defend the science requirements? Interesting questions, these.

Compounding the problem is the rapidly changing world condition which begs for more scientific manpower. Some of our most able young people are avoiding science classes in our colleges and universities and in our high schools at a time when world dependence on technological capability is increasing. It is hardly heresy to suggest that the solution to these problems of survival will be heavily dependent on science and technology.

The objective sought is a rebirth of interest and respect for both the contributions and the limits of science and technology. Needed is both a respect for and ability to use knowledge in the library of science. While only a few workers will be employed in the production of new scientific knowledge, essentially all will need at least occasional visits to this library. Also sought is a substantial increase in interest and understanding of how science and technology contribute to the general welfare of our society and our human and humane culture, along with some vision of what can be expected in the future in terms of social values and scientific and technological applications. Our objective must also include concern for students' ability to

identify and use the processes of science which are instrumental in learning how to learn. It's a lifetime process. And finally, students need an understanding of science as a societal enterprise whose product is new knowledge which is an investment in the future and some tools for dealing with scientific and technological developments which may be labeled "dangerous." What is sought is a population which is conversant with the four faces of science as in the operational definition and comfortable with both their intent and extent.

MEETING THE NEED: ALTERNATIVE POSSIBILITIES

The current situation requires that we broaden both the scope of what is taught and expand the market of students. In a period of economic exigency, massive regeneration of curriculum development will not be experienced as it was in the 50's and 60's. The curriculum revisions will come slowly as will the "adoptions." Neither can we expect a major influx of newly trained teachers. As a matter of fact, the students who will inhabit our high school programs for the next fifteen years have already been born. It is easy to count them and to determine that the demand for new science teachers will not expand, but will certainly decrease. Therefore, our alternatives include the gradual development of promising new courses and/or the more rapid development of supplementary materials which can be incorporated into existing courses.

- - CURRICULUM DEVELOPMENT

Curriculum development projects are underway which stress interdisciplinary approaches to the sciences. In various local districts, teachers are developing an integrated or unified science program (8). Through their efforts, the scope of science education is being broadened, but this unified science requires a major restructuring of the curriculum and full commitment of teachers and the support of school administrators. In a period of shrinking economic resources, it is unlikely that this kind of support will be available on a broad

scale basis throughout the nation. The effort is to be applauded, yet its impact is not likely to sweep the nation.

A second example of new curriculum offerings focuses on the man-environment problem. Some of these curriculum efforts are well conceived and retain the integrity of the basic sciences while appropriately citing environmental applications. Investigating Your Environment (9) is an example. Unfortunately, it will only slowly find its way into the nation's schools and then only for a fraction of the students. Interdisciplinary Approaches to Chemistry, I.A.C. (10), provides an example of instructional modules which cut across the biological sciences, the earth sciences and the physical sciences. Chemistry is presented "as an exciting, relevant human activity that can be enjoyable to study." Numerous implications and applications are used to build a solid course which emphasizes basic skills and concepts of chemistry. Again, the wide-spread adoption will be slow. Many other commercial publishers have added societal and environmental concerns to their publications. Unfortunately, data are not available on the extent to which these texts meet the criteria for science literacy as outlined above, nor are data available on the extent to which these texts are being adopted in schools across the nation.

Such curriculum development is necessary and appropriate, but not sufficient. What is needed is a strategy which will:

1. Prompt the development of new supplemental teaching materials specifically directed toward developing science literacy

2. Be attractive enough to encourage teachers to incorporate the strategy and materials in their teaching without retraining

3. Result in increased literacy in science, as defined above

- - AN ALTERNATIVE: SUPPLEMENTARY MATERIALS

In the remainder of this paper, I want to suggest "the future" as such a teaching strategy for developing science literacy, and outline the development

of "future-oriented teaching materials" which can be used as a supplement in the present science curriculum.

This will require at least a partial reversal of the time orientation of instruction in the sciences, since most science instruction is oriented to the past. The classes and the text focus on theories and principles developed in another culture and time. It's also difficult for students to relate to living scientists, since the students' experience with science is limited to that which goes on in the classroom. From their point of view, this has very little to do with the real world. In most cases, there is very little opportunity to explore what you and I may think of as the dynamics of science. The two-fold problem of orientation toward the past, with a restricted reality of science, makes the development of science literacy quite difficult.

Added to this is the problem that many of current texts, at the high school level, have been stripped of many social or technological applications. Future-oriented teaching materials would ask students to project new or novel applications of existing scientific knowledge and to assess the consequences of this on themselves, their families and their friends. Note that this requires the student to project himself into the future, to monitor social, political, economic and cultural changes, and to decide the good and bad points of the particular "future." A second family of possible future-oriented activities calls for the creative formation of new scientific knowledge. Such "new knowledge" can be reviewed in terms of presently accepted knowledge and in terms of constraints of presently accepted assumptions about the world. This game of "new knowledge" should force students to more carefully explore our present knowledge system, which is one of the aspects of the long sought science literacy. This game also raises the ominous question

of dangerous knowledge. Who is to determine how this new knowledge will be used? Under what rules? This is not a standard science exercise, but it is typical of the questions which confront many areas of society today, including medicine and law.

Such supplementary teaching materials, effectively developed and used, would not diminish the students' contact with the scientific disciplines, but would enhance it. Properly used, these materials can encourage interdisciplinarity, prompt exhibition of applications of scientific principles, confront students and teachers with moral value and cultural questions of future scientific and technological developments, lead students and teachers alike to explore the workings of science and scientists, prompt students to develop monitoring or feedback systems from their invented future and develop in students a future-oriented possibility for their role in science and in society. In short, the use of future-oriented teaching strategies can lead to a more comprehensive view of science and of the world. I propose that we have a mechanism here for developing science literacy which will complement science and meet critical social needs.

THE FUTURE AS AN ORGANIZING PRINCIPLE

The decision to choose the future as an organizing principle for science literacy was not made lightly. It was based on the following:

A. The future as an indegenous concern of science. The structure of science includes well-defined rules and procedures for explanation, prediction and refutation.

B. The future as a prominent concern of society. The rate of change in our world society has accelerated to such an extent that projections such as population growth, energy needs and atmospheric deterioration have become societal imperatives.

C. The future as a potent teaching tool. Means of dealing with issues, policies and problems developed by corporate think-tanks and universities have shown great promise for transforming the learning environment by focusing on means of creative problem-solving and decision-making. These techniques should be extensively explored at the high school level.

Each of these points bears further examination.

- - THE FUTURE AS AN INDEGENOUS PART OF SCIENCE

Science, among all of the disciplines, has evolved the most well-documented paradigms for explaining and predicting events and for emperical verification or refutation of predictions, forecasts and explanations. Hempel (11) describes the predictive paradigms of science in the following way:

> "The function of general laws in scientific prediction can now be stated very briefly. Quite generally, prediction in empirical science consists in deriving a statement about a certain future event (for example, the relative position of the planets to the sun, at a future date) from (1) statements describing certain known (past, present) conditions (for example, the positions and momenta of the planets at a past or present moment), and (2) suitable general laws (for example, the laws of celestial mechanics. Thus, the logical structure of a scientific prediction is the same as that of a scientific prediction is the same as that of a scientific explanation, which has been described... In particular, prediction no less than explanation throughout emperical science involves reference to universal empirical hypotheses.
>
> "The customary distinction between explanation and prediction rests mainly on a pragmatic difference between the two: while in the case of an explanation, the final event is known to have happened, and its determining conditions have to be sought, the situation is reversed in the case of prediction: here, the initial conditions are given, and their "effect"--which, in the typical case, has not yet taken place--is to be determined.
>
> "...Even the laws and theories of the physical sciences do not actually enable us to predict certain aspects of the future exclusively on the bases of certain aspects of the present: the prediction also requires certain assumptions about the future. But in many cases of nomological prediction, there are good inductive grounds available...for the assumption that during the time interval in question, the system understudy will be practically "closed," not subject to significant outside interference."

However, in the school science curriculum, students should be asked to go beyond the bounds of the usual domain of the physical and biological phenomena to consider social and cultural changes associated with these sciences. Some educators may object to this claiming, rather, that science classes should be limited to studying isolated, idealized phenomena. But expansion beyond these limits is an essential part of science literacy. By examining

projected societal events, students will not only learn of the implications and applications of science, but also will learn about the domain of science, its rules and its limits.

Nagel (12) describes, at length, the methodological problems of science and contrasts these with their counterparts in the social studies. His discussion sheds valuable light on some of the constraints and limits encountered in applying methods and ideas of the natural sciences to social science phenomena. The optimum means by which future-oriented teaching materials can be developed remains to be determined. However, it is clear that science already contains the structure for predicting future events, and for assessing the impact and validity of these predictions. This aspect of science, which has received relatively little attention within the school curriculum, can be used as a mechanism for turning around the time orientation of what is taught. By this expansion of science-based materials to the social level, we have uncovered the second rationale for using the future as an organizing principle.

- - THE FUTURE AS A SOCIAL IMPERATIVE

The physical impact of science and technology is felt almost everywhere except in our schools. It is as if the impact of science and technology were as obscure as the proverbial tree in the forest. The impact that technology has had on reshaping the earth's surface and on our total environment is reasonably well known in terms of physical structures, automobiles, strip mines, etc., yet the school texts have decreased emphasis on technological development. The impact that the extensive developments in the physical sciences have had on our creature comforts, our way of life and our perception of the world has been reasonably well researched. The impact of the biosciences on our health, population, beliefs and values has long been discussed, but rarely finds its way into the school curriculum. The extent of

the impact of recent developments in the biosciences is only now beginning to dawn on us in terms of bioengineering, transplants and personality control. Unfortunately, very little of this reaches the high school student. Such discussions are not found in the social studies curriculum (13) and very little discussion of these topics is found in the science curriculum.

Major problems of the world, such as [illegible] population, rampant consumerism, energy, resource depletion and environmental changes are abundantly related to developments in science and technology. The Stockholm Conference on the Environment and the World Food Conference in Rome have examined several of these basic questions of survival. But where are these issues to be found in the high school curriculum. The works of the Club of Rome, which include the Limits to Growth (14), and the more recently published Mankind at the Turning Point (15), are clear indications that the concerns of science and technology on mankind are, indeed, concerns of survival. Yet most of our students are graduating from high school unaware of these developments and not prepared to deal with these problems. They are, in fact, largely unaware of the ways in which science and technology are being used to reshape the earth and human life.

The cultural impact of science and technology has grown considerably over time. The "Two Culture" argument posed by C. P. Snow remains essentially unresolved. Science and technology stand as perhaps our most potent forces for changing values and cultural patterns, yet we choose not to look at the impact that a scientific development may have on the human condition. We will not discover this by continued emphasis on scientific principles isolated from culture. We need to build a bridge with the humanities to the future. Teilhard de Chardin (16) provides us with one approach.

In his Phenomenon of Man he says,

> "Of old, the forerunners of our chemists strove to find the philosopher's stone. Our ambition has grown since then. It is no longer to find gold, but life; and in view of all that has happened in the last 50 years, who would dare to say that this is a mere mirage? With our knowledge of hormones, we appear to be on the eve of having a hand in the development of our bodies, and even our brains. With the discovery of genes, it appears that we shall soon be able to control the mechanism of organic heredity. With the synthesis of proteins imminent, we may well one day be capable of producing what the earth, left to itself, seems no longer able to produce: a new wave of organisms, and artificially provoked neo-life. Immense and prolonged as the universal grouping has been since the beginning, many possible combinations have been able to slip through the fingers of chance and have had to wait man's calculated measures in order to appear. Thought artificially perfects the thinking instrument itself: life rebounds forward under the collective effects of its reflection. The dream which human research obscurely fosters is fundamentally that of mastering, beyond all atomic or molecular affinities, the ultimate energy of which all other energies are merely servants; and thus grasping the very mainspring of evolution, seizing the tiller of the world."

Although de Chardin's work appeared in English in the 1950's, he is telling us of a future yet to unfold. It is a future which students will direct, whether or not we prepare them for it.

The humanities represent the finest in human culture--an expression of our values and beliefs. Yet, the sciences have drastically reshaped our values and our beliefs in the past 100 years. In de Chardin's words, we have our hand on the tiller of the world. To what extent are we willing to act? To what extent are our present students even aware of the moral and philosophic questions involved in our manipulating our own evolution? Are they even able to understand the question? Yet, tomorrow they may be called on to give an answer. Indeed, from this point of view, the future is a societal imperative which must be incorporated into the school curriculum.

Some of the developments, particularly in the biosciences, lead to serious questions about the future of the human race. Some of this knowledge

has been referred to as dangerous since it readily lends itself to misapplication. The concept of dangerous knowledge is not new. It has appeared in many other cultures and many other times. The usual remedial action is suppression. Yet how do you suppress knowledge of the atom or of genetic structure or synthesis? Potter (17) examines the concept of dangerous knowledge as follows:

> "The feeling grows that scientists are finding it increasingly difficult to predict the consequences of their work, that technology has become the sorcerer's apprentice of our age. The concept of dangerous knowledge appears in a variety of images--the mushroom cloud, the usurping robot, the armless child of thalidomide. Many scientists object violently to the idea of dangerous knowledge, taking the position that all increases in knowledge are inherently good. This attitude is undoubtedly interwoven with our religious heritage, which assumes that the world exists for the benefit of man and that human suffering and evil serve part of a greater purpose. I believe that the concept of dangerous knowledge is valid, if for no other reason than that it calls attention to one of the dilemmas of our society. Dangerous knowledge has been defined as knowledge that has accumulated faster than has the wisdom to manage it; in other words, knowledge that has produced a temporary imbalance by outpacing other branches of knowledge.
>
> "Basically, the problem arises from the gulf that is driven between the knowers or scientists and the doers or technologists. The expanding scientific enterprise appealed to its own practitioners, the knowers, on abstract grounds, as a mode of progressively uncovering the truth --a good in itself. But it also drew the support of a widening circle by its demonstrable utility in improving the ways of doing. The knowers hesitate because knowledge is never final, and the number of possible combinations of hazards is always greater than the number of individual hazards. Pragmatism, however, has always been the test of success in our culture, and our technology has proceeded almost on the basis of a single motto: 'If it can be done, and sold at a profit, let's do it.' This viewpoint may seem in harmony with the world of the conservatives, but in fact it has been most responsible for changing that world.
>
> "The consequences of new knowledge have always been unpredictable--hence Michael Faraday's classic remark in 1831 when asked what good is electricity: 'Sir, what good is a new-born baby?' The present world differs from that of Faraday, particularly in the speed with which technology seizes upon new knowledge and converts it to action that will combine with other actions in ways that are unpredictable. In a world so rapidly absorptive, all new knowledge is potentially dangerous, but the word 'unpredictable' needs qualification. The danger of new knowledge lies only in its application, and the unpredictability prevails to a very great extent because no specific effort is made to foresee the consequences and the interactions that may result from that application."

Potter calls for the establishment of a Council on the Future to examine the consequences of some of our technological applications. He goes on to argue that the only answer to dangerous knowledge is more knowledge rooted in wisdom. He says:

> "Perhaps what is needed is not conservatism or liberalism but realism --realism about the nature of man and realism about the nature of the world we live in. We are now talking about what every educated person ought to know and does not. There is not presently available within a single cover any reliable authoritative summary of what one would hope a college graduate, or even a high school graduate, might be expected to know about man and his world and the relationship between order and randomness in each. Knowing involves knowing what we do not know as well as what we do know, and there is little doubt that if a group of the best minds from seven continents were mobilized, they could come up with surprisingly large areas of agreement on knowledge and ignorance."

These comments force us into a future frame of reference. To what extent have our students explored this frame of reference, or thought about dangerous knowledge. It's easy to see how science and society could be turned toward the dark ages if fear directs our actions rather than knowledge and wisdom. Potter's words have some very cogent meaning for those concerned with science teaching and science curriculum development.

These two views of the impact of science and technology on mankind suggest a philosophic and cultural optimism that man can continue to understand his own condition and, in fact, have a hand in his own evolution and that with this knowledge will come the wisdom of how to use it. As Potter expressed it, the only solution to dangerous knowledge is more knowledge. What is evolving is a picture of science and technology which is missing from the present school curriculum. The first step of bringing these concerns to the American people is more likely to be met when a future orientation is adopted within the science curriculum.

The social, political and economic impact of science and technology need to be more prominently displayed. One example will suffice: Energy.

Projections of energy needs and problems for the next five years would add a measure of relevance to the science curriculum which would be hard to match. The questions of scientific knowledge, research and national needs present an interdisciplinary problem which is in reality a great opportunity.

The popular image of science referred to elsewhere in this paper continues to deteriorate. This is not surprising since many of the major environmental problems have been tied to scientific developments. Science appears to be the culprit. Very little positive information is available within the school curriculum to present a balanced view. Science education appears to be letting both the image and the market slip from its grasp. The hope of new scientific developments, the limitations and our ability to deal with the misuse of scientific knowledge, all are important aspects of science literacy.

- - THE FUTURE AS A STRATEGY FOR LEARNING

Planning and decision-making, fundamental human activities, are frequently not taught explicitly at the high school level, but are covered implicitly in various areas of the curriculum. It is suggested in this paper that using the techniques of planning the future will result in a significant increase in both planning and decision-making capabilities.

Toffler (18, 19), author of Future Shock and Learning for Tomorrow - The Role of the Future in Education, discusses the many ways in which futuristics should, can and are being incorporated into the classroom. In one sense he is saying that the schools need to be transformed so as to more adequately deal with the social changes we are experiencing, including the questions of permanence and impermanence. Shane (20) has argued even more vigorously for this approach in his recent publication, The Educational Significance of the Future. This is a major transformation for the schools.

Science, as suggested in this paper, provides us with a model of reasoned change, where we stand firmly on what we know and construct theories to predict future events which, in turn, can be carefully assessed in terms of the results of our observations. In other words, science presents us with a model for future-oriented learning, which is based soundly on accumulated knowledge with feedback systems for obtaining data by which we can assess the creditability and the value of our projections.

In summary, the future is a logical organizing principle with which to develop science literacy. Its adoption, as an organizing principle, would enhance, not detract from the teaching of science including scientific knowledge, the processes of science and the nature of science. Clearly, it is closely tied to social imperatives and appears to have great educational potential as a tool for learning. From all of these points of view, it seems not only a rational but an ideal means to use to increase the literacy in science for future generations, while retaining the strength of the subject matter content of our present courses.

FUTURE-ORIENTED CURRICULUM UNITS IN SCIENCE

Students who are studying science at the high school level are engaged in learning about the mechanisms by which the human condition will be changed. In a way, they are exploring the knowledge which will be used to invent the future. Wren-Lewis (21), in discussing the education of scientists, states that "their scientific education is fatally incomplete if it does not include, as an integral part of their discipline, some explicit training in how to think about the kinds of future that may be in store for mankind." This statement is equally applicable at the high school level, since it is only at this level that the majority of American citizens experience formal instruction in the sciences.

There are two views of using future-oriented instructional materials in the classroom. One states that the study of the future is a justifiable end in itself. The second view uses the future-orientation as a mechanism for allowing students to personally identify with issues and knowledge, and to explore and learn the societal/cultural implications of this knowledge, while retaining the basic content and objectives of the science curriculum. This second view allows continued identity with the content and structure of the disciplines, which is a fundamental value assumption in science education, and will be repeatedly stressed in this paper.

The first of these views, that which supports the separate course on futures, has as proponents, Toffler (19), Shane (20) and Theobold (22). Rojas and Eldredge (23) have identified a number of college-level courses which deal with futuristics. These include "Futurism and Long-Range Planning" at Dartmouth College, "Alternative Images of the Future" at Syracuse University and "Technological Forecasting" at Stanford, and "Sociology of the Future" at St. Louis University.

One of the first high school futuristics courses was taught at Melbourne, Florida High School in 1967. More than 20 high schools are listed as currently having courses on futuristics.

The adoption of "futures" seminars and courses seems premature for use in the sciences at the high school level. It is difficult to chart the future when the basic tools of scientific knowledge are not yet developed in the student. It is difficult to examine the significance of biological research when the fundamentals of biology are unknown. It is an obvious conclusion that before such instruction can be meaningful, the basics of science and mathematics must be in hand. Wren-Lewis agrees. He states "instead of a general vague plea for liberalization, what is now emerging from the industrialists who have studied the question most seriously, is the idea that scientific education at all levels

should be widened by a logical extension of its own basic principles to include training in the art that has begun to develop over the past decade in the various 'futures think tanks,' large and small, that have sprung up across the world under a variety of names and sponsorships--namely, the art of thinking systematically about possible futures for human society on various segments of this planet, in such a fashion as to integrate specialized scientific thinking with psychological and sociological insight and humane imagination."

This view requires that as the basic principles and theories of biology, chemistry and physics are being taught, that forecasts of their application and implications in society be given prominent attention. This procedure would not require massive rewriting of the curriculum, nor would it supplant the existing curriculum. What would be needed are materials to supplement the existing texts and laboratories to open the windows to the future for students and teachers.

Teacher-based units are needed with societal applications keyed to the general units found in high school texts. For example, a futures unit could be developed to supplement the life science and biology units on genetics. These materials could follow the scenario foremat in which alternative futures are "forecast." Such materials could vividly expose some of the scientific processes of explanation and prediction, as well as some of our current assumptions about the nature of the world and the nature of life. Students could be directed to develop strategies for feedback from these alternative futures so that, together as a class with their teacher, they can examine the socio-cultural implications and perhaps, uncover areas which have been referred to earlier as dangerous knowledge. The argument that such materials would detract from the existing curriculum hardly seems valid when already today our courts are being asked to establish judicial definitions for life processes that were not even questioned in the textbooks of yesterday, and when parts of the scientific community have

called for a moratorium on some research. That such an approach meets the foregoing definition of science literacy should be clear. Properly constructed, these teacher-based units include the knowledge of science, the processes of science, the nature of science and the socio-cultural implications of science.

Instructional material development is also needed in the area of student-run projects. These alternative future modules could be designed for the individual student or small groups of students. Many of these modules could focus on significant scientific problems which cut across the usual disciplinary boundaries, as well as across time. Current literature is replete with data and projections on energy utilization over the next twenty years. Adequate exploration of alternative solutions to various parts of the energy problem would require students to explore, in depth, decision-making processes such as outlined in the Man-Made World, which include model construction, specification of criteria referenced to the goals or objectives; constraints which may be invented for the future condition and specification of the optimum solution. Exploration of this decision-making process is, itself, a worthy educational goal.

A second example is suggested by the study of photosynthesis. In this alternative future module, the student could forecast the social, political, economic and technological consequences which would accompany man-made control of the photosynthetic process, allowing rapid and controlled synthesis of inorganic materials into organic molecules (foodstuffs). Techniques of impact analysis, extrapolation and mathematical model-building could be employed.

The teacher would employ a modified form of the delphi technique to arrive at a concensus. The contrast between this technique, as employed in social settings and the procedures of confirmation and refutation employed within science, would provide an excellent basis for discussion of the nature

of science. Simulation models can be constructed either in paper and pencil format, three-dimensional models or, where appropriate, mathematical models. Scenarios can be constructed to focus attention on decision points and value conflicts in the alternative futures. Some of these units might even employ the technique of experience compression to point out that the societal consequences of some developments move very slowly, so slowly, in fact, that their detrimental consequences may not be appropriately apprehended.

- - BENEFITS AND COSTS

Anticipated benefits and costs can be examined in terms of beneficiaries: society, the scientific community and our students.

Society benefits by having a new generation of voters cognizant of the values of science, schooled in exploring value systems subjected to change by new scientific knowledge and aware of the fundamental importance of adequate feedback for assessing the implications of decisions. In short, society would benefit by having individuals more able to deal with the scientific and technological problems described by the National Science Foundation in the report quoted earlier in this paper. The costs to society are minimal and represent only those added costs for the production of appropriate, supplemental curriculum materials.

Benefits to the scientific community would accrue by having a new generation of scientists who were aware of the social and cultural implications of their work, and who would have experienced both the strengths and shortcomings of the scientific processes and methods when applied to social phenomena. It is likely that the scientific expertise of the individual would not be diminished, but would, in fact, increase as his science literacy quotient increases. The cost of this change in science education might be assessed as enormous by the scientific community, since this view apparently denies the amorality of

of science. On the contrary, it can be argued that this type of learning more adequately defines those areas of science for which amorality can be both important and appropriately claimed. In other words, the cost to the scientific community must be viewed as small. It should be noted that it is also likely that the public's perception of science would be greatly improved.

The students, fortunately, would be the major beneficiaries of the proposed change. An obvious benefit has been described by Singer (24) as a future-focused role image. In this view, the student identifies with aspects of the alternative futures being considered, and places himself or herself in role situations within that future. Such developments, if Singer is correct, could have a significant impact on career plans and ultimately on enrollments in science. Students will also be led through the future-oriented materials to frequent journeys to the immense library of scientific knowledge to explore, meaningfully, the use of the processes of science, to examine the nature of science and to consider, analytically, the social and cultural implications of scientific developments. In short, students will be led to a fuller level of literacy in the sciences.

RESEARCH QUESTIONS

The proposal presented in this paper outlines some of the ways in which alternative instructional materials can be developed for achieving science literacy, making use of the future as an organizing principle. There are several research questions implied in this procedure concerning the mechanisms by which these materials can be developed and their curricular use demonstrated, and the more fundamental questions about the extent to which such materials, incorporated into existing curricula, can bring about an increase in literacy in the sciences, as defined.

To date, no system has been developed for assessing student achievement in the identified areas of science literacy, other than knowledge, with occasional attempts to assess learning in the processes of science and in attitude towards science. These techniques need to be developed and some integrated measure of science literacy proposed and validated. There is also a need for some ongoing service available to teachers which will provide formative, diagnostic information on the four aspects of science literacy identified in this paper. Such a national service would not only provide teachers with diagnostic data on students, but would also provide the science education community with extremely valuable, hard data on science literacy in our nation's schools.

Fundamental research questions also arise about students' ability to deal with future-oriented topics. To what extent can students handle such abstract ideas, and how is this ability related to cognitive age, to sex and cultural differences? Finally, studies are needed which are longitudinal in nature and which assess both student interest in science, and which measure changes in enrollment patterns in the nation's science classes.

SUMMARY

In this paper, an operational definition of science literacy was presented as including knowledge of science, the processes of science, the nature of science and the social implications of science. Future-oriented supplemental teaching materials were proposed as the most viable alternative available for achieving literacy in science within the present school curriculum, with a minimum of investment and with little or no retraining of present personnel. The proposal to use the future as an organizing principle was based on the recognition that future-oriented rules and procedures are an indigenous part of science, and that future projections and plans are a crucial part of our

current social structure. Reference to the educational utility of future-oriented learning exercises was also presented. Selected samples of future-oriented, teacher-based materials were presented, along with several samples of student-run projects, also future-oriented. The benefits and costs were described in terms of social utility, added benefit to the scientific community and fundamental benefits to students. Finally, research questions were posed which focused on the assessment of science literacy, as defined, along with additional basic questions about students' ability to deal with future-oriented topics as a function of cognitive age, sex differences and cultural differences.

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